Characterization of the Tortugas Ecological Reserve

Phase I - Establishing a Baseline & Phase II - Measuring the Effect of Establishing a Reserve

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National Centers for Coastal Ocean Science
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ANNUAL REPORT

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National Oceanic and Atmospheric Administration
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National Centers for Coastal Ocean Science
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Comparative analysis of the functioning of disturbed and undisturbed coral reef and seagrass ecosystems in the Tortugas: Phase I- Establishing a baseline

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Annual Report

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EXECUTIVE SUMMARY

Almost 50 days at sea, aboard three NOAA Research Vessels, were used this past Fiscal Year to support our baseline characterization of the Tortugas Ecological Reserve (TER). In TER South, seafloor transect surveys were conducted using divers, remotely operated vehicles (ROV) and the *Deepworker* manned submersible. ARGOS drifter releases, satellite imagery of water mass composition, ichthyoplankton surveys and direct diver census were all combined to elucidate the potential down-current dispersal of fish spawning in this environment. Seafloor surveys are being compiled into a GIS that will allow resource managers to gauge benthic resource status and distribution (baseline). Drifter studies have determined that within the ~ 30 days of larval life stage for fishes spawning at TER South, those larvae could reach as far downstream as Tampa Bay on the west Florida coast and Cape Canaveral on the Florida east coast. Taken together with the actual fish surveys and water mass delineation, this work clearly demonstrates that protection of this area has tremendous downstream "spill-over" potential for Florida reef habitats and the maintenance of their fish communities.

In TER North, 30 randomly selected, permanent stations were established. Ten stations were assigned to each of the following areas: within the existing National Monument (Park); within the Ecological Reserve (Reserve); and within areas immediately adjacent to these two strata, but remaining in comparatively unprotected status (Out). Intensive characterization of these sites was conducted using multiple sonar techniques, towed video (TOV), ROV, diver based digital video collection, diver-based fish census, towed fish capture, sediment particle-size and benthic chlorophyll analyses, and representative stable isotope analyses of primary producers, fish and shellfish. Preliminary isotope data, in conjunction with our prior results from the west Florida shelf, suggest that the shallow water benthic habitats surrounding the coral reefs of the TER will prove to be the source of a significant amount of the primary production ultimately fueling fish production throughout the TER and thus, downstream throughout the range of larval fish dispersal. Therefore, the status and influence of the previously neglected, non-reef habitat (comprising over 70% of the TER) appears to be intimately tied to the health of the coral reef community proper.

These data, collected in an integrated design at multiple spatial scales, leave us poised to continue and expand this effort in FY2002 to begin measurement of the post-implementation effects of the TER. Combined with the work at TER South, this project represents a multi-disciplinary effort of sometimes disparate disciplines (fishery oceanography, benthic ecology, food web analysis, remote sensing/ geography /landscape ecology, and resource management) and approaches (physical, biological, ecological, geochemical). We expect that the continuation of this effort will yield critical new information for the management of the TER. Moreover, this integrated approach represents a new and important direction in the assessment of the Sanctuary and Reserves Division's protected marine environments and the TER in particular.

BACKGROUND

On July 1, 2001, the nation's largest, permanent, marine no-take reserve within the conterminous United States was opened in the Dry Tortugas. The Tortugas Ecological Reserve encompasses 151 square nautical miles and is composed of two separate areas: Tortugas North and Tortugas South (Figure 1). Tortugas North covers the northern half of Tortugas Bank, Sherwood Forest, the pinnacle reefs north of the bank, and extensive low relief areas in the 15 - 40 m depth range (Figure 1). This area will remain open to diving.

Tortugas South includes Riley's Hump as well as deep water habitats to the south (Figure 1). Based upon published information and interviews with experienced commercial fishermen, Riley's Hump has been identified as a potential spawning site for five commercially important snapper species (Lindeman et al., 2000). Other commercially important species are supported by the deepwater regions of Tortugas South, including snowy grouper, golden crab, and tilefish. This region is open only to vessels in transit and to Sanctuary permitted researchers and educators.

The National Centers for Coastal Ocean Science, here headed by the Center for Coastal Fisheries and Habitat Research (CCFHR) and our colleagues both in and out of NCCOS (Center for Coastal Monitoring and Assessment), Coastal Services Center (CSC), Florida Marine Research Institute (FMRI), National Undersea Research Center (NURC), and the University of South Florida (USF), are uniquely poised to provide critical mission support to habitat characterization and marine reserve questions that are facing the Tortugas Ecological Reserve (TER) within the Florida Keys National Marine Sanctuary (FKNMS). CCFHR has researched fishery-habitat interactions in south Florida and the Keys since the early 1980's and brings a wide range of scientific expertise to bear on fisheries and habitat issues. Moreover, we are coordinating this work with the research approach and philosophy of applied studies of our other studies in the region - including injury recovery experiments, monitoring and modeling in the FKNMS, linkages among coral reefs and adjacent habitats in Puerto Rico, EFH funding on the contribution of deepwater primary producers to coastal fisheries, gear impact studies, and long-term studies of icthyoplankton distribution, development and transport mechanisms.

The need for detailed habitat characterization is inextricably linked with the reserve issue. Many reef fishes leave the structure of the reef at night to forage in the adjacent sand, algal and seagrass flats, thereby importing significant amounts of nutrients onto the reef environment, contributing to its high productivity. This mass transfer also ultimately contributes to energy requirements of small grazers that cannot themselves access the adjacent, non-coral reef resources. The adjacent seagrass beds are also significant settlement areas for post-larval reef fishes. Over-fishing of the diurnally migrating fishes and/or physical damage to the foraging/settlement environment could significantly alter the reserve's productivity and biological diversity. Therefore, habitat characterization is critical to determine the distribution of sessile resources that are susceptible to injury and which may be poised to rebound once any injurious activity is relaxed through implementation of the reserve.

The Riley's Hump area of TER South also provides us with a setting to expand the investigation of downstream or spillover effects of a protected marine environment with Ecological Reserve status. Past work in this area has demonstrated that fish spawned on the west Florida shelf can provide recruits over long distances downstream. We expand on this work through studies of larval fish distribution and life history, combined with drifter releases and study of satellite imagery to provide a synoptic assessment of the potential role that TER south can itself play in the maintenance of fish communities elsewhere in the Floridian province.

Conducting work in the TER provides a unique opportunity to compare the structure and function of a relatively undisturbed system with those elsewhere in the FKNMS and adjacent waters. This comparative approach has significant potential for translating the findings of these studies so as to apply them directly to management issues in other NOAA trust resources. Findings from this study will be directly applicable to marine protected areas (MPA) elsewhere in NOAA's jurisdiction.

OBJECTIVES

Over the three year period of this work, we proposed:

1) a preliminary characterization and inventory of the benthic habitat and fish communities in the extreme depths of the Tortugas South reserve component;

2) characterization of spawning aggregations and initiation of the development of a probabilistic model of the fate of snapper larvae, focusing on Riley's Hump;

3) beginning comparative characterization of shallow and deepwater seagrass communities and their contribution to fishery resources in disturbed (outside reserve) and undisturbed sites (inside reserve);

4) establishment of a baseline for benthic nutrient composition and flux in disturbed and undisturbed sites;

5) determination of the accuracy of existing habitat delineations within the proposed ecological reserve as a function of depth and disturbed and undisturbed sites;

6) examination of how high resolution ecological data of a given habitat type can be scaled to the larger spatial context of the proposed ecological reserve.

METHODS

Cruises:

This fiscal year, five cruises, utilizing three NOAA ships, have been conducted in support of this research (Table 1). Details of these cruises in the form of combined progress/cruise reports can be found at: http://shrimp.ccfhrb.noaa.gov/~mfonseca/reports.html.

Table 1. Completed research cruises.

Cruise Name	Dates	Vessel	Sea Days
OT-01-01	04 January 2001 - 13 February 2001	NOAA Ship Oregon II	8
FE-01-07-BL	08 April-2001 - 20 April 2001	NOAA Ship Ferrel	12
FE-01-10-BL	17 June 2001 - 01 July 2001	NOAA Ship Ferrel	13
FE-01-11-BL	08 July 2001 - 21 July 2001	NOAA Ship Ferrel	13
GU-01-03	02 July 2001 - 03 July 2001	NOAA Ship Gordon Gunter	2
		TOTAL DAYS AT SEA	48

Habitat Characterization:

In the summer of 2000, before the Reserve was established, we conducted extensive habitat mapping in areas falling within and outside the proposed reserve. Specifically, the area was divided into two strata: use and depth (Figure 2). Use was broken down into the existing Dry Tortugas National Park (DTNP), the proposed reserve not falling within the existing jurisdiction of the DTNP, and a 5 km buffer around the proposed reserve for before/after comparisons, again not within the DTNP. Within each use category, three depth strata were arbitrarily defined as: 0-15 m (shallow), 15.1-30 m (medium), 30.1 m + (deep). The entire sample universe was broken into 1 km square grids which were randomly chosen from within each strata for sampling. Precise sample locations from within each square km were also randomly chosen at 1 m resolution through additional sub-sampling and locating of coordinates in the field by use of survey-grade DGPS (Trimble Pro XR®). At each sample point, we conducted extensive benthic mapping using a MiniBat® TOV housing a vertically-mounted camera (SeaView®)and Quester Tangent® (QTC) seafloor classification sonar system (Figure 3). An additional sonar system (ROXANN®) was deployed on most transects and run simultaneously with the MiniBat unit. Three passes of approximately 1 km in length and separated by a distance of ~ 200 m were made at each point (Figure 4). For the deepwater habitats at Tortugas South, depth stratified transects (100' increments) were mapped using the Phantom ROV S-2 graciously loaned to us by NURC and operated by NURC staff (Figure 5).

After review of the first year of data we discovered formidable logistical issues involved in sampling this area and so chose to adopt a sampling protocol that focused on habitat interfaces (i.e. areas where coral reef meets seagrass/algal plains) using randomly selected, permanent transects. Our video interpretations and drop camera work from that year revealed extensive areas of potential interfaces - essentially running around the entire perimeter of Tortugas Bank and the National Monument.

The decision to focus sampling at the habitat interface was based upon several ecological considerations. The interface, or boundary (also may be termed “ecotone”), is used in two fundamental ways in sampling designs. One approach is to use boundaries as ways to stratify sampling, thereby limiting sampling to within a certain class of conditions (e.g. habitat type) and reduce sample heterogeneity. The other approach is to focus on the boundary itself, especially when the exchange or movement of resources (propagules, migrating fauna, energy, nutrients, etc) is of special interest. We take the latter approach because these boundaries are not absolute and we hypothesize that energy flow across these boundaries is critical to understanding changes among strata as the result of Reserve implementation. We make this hypothesis because our previous work on the nearby west Florida shelf reveals that the primary producers driving fish production, even fishes captured on hard bottom areas, are the benthic micro and macroalgae and the deep water seagrass, *Halophila decipiens*. This fact, taken with the observation that over 70% of the TER is non-coral habitat, leaves us to hypothesize that the areas surrounding the coral formations are a crucial source of energy for the maintenance of the coral reef ecosystem. Finally, considering that predation is often high in low relief areas, especially at interfaces, the structure and composition of fish communities near these interfaces, along with the physical landscape context, should be areas where changes should fast become evident, if they occur at all.

To be able to detect these changes, given the logistics of requiring a research ship on station and working at considerable depth (average depth at the interface was approximately 85 feet - working with NITORX II allows us only 50 minutes of bottom time and > 12 h to eliminate all residual nitrogen in the bloodstream before returning to that depth), we adopted a BACI (before - after control impact) sampling strategy. However, we have the added advantage of not only the unaltered, Out strata as a control, we have the Park as a long-term control and potential comparative sample representing a mature community, free from consumptive harvesting impacts. With the permanent transects in place and time zero data in hand (“before”), we are now poised to conduct the “after” assessments and document the efficacy of the TER designation.

The random selection of permanent transects allowed us to stratify sampling by Reserve (new areas going under protection), Park (areas within the National Monument that had been under protection for decades) and Out (areas that remained in current use status). The interface zones along both of the large reef structures in TER North (Tortugas Bank and the National Monument area) were further designated as one of six categories: Out North (outside the reserve/park, north of the prevailing current - which runs roughly northwest to southeast) Out South (outside the reserve/park, south of the prevailing current), Park North (inside the park, north of the prevailing current), Park South (within the park, south of the prevailing current), Reserve North (within the reserve, north of the prevailing current), and Reserve South (within the reserve, south of the prevailing current, Figure 6).

To choose the five random transects from within each of the six categories, we used ARC/INFO software and imposed a line at roughly the 10 fathom isobath around the perimeter of the two large coral features. Each line was then broken down into the six categories and random distances along each line type were selected.

The assignation of random locations along line type was continuous across the entire landscape, even though line types were segmented among the two large coral features, yielding true randomization. Random points were spaced 50 m along segments so that visual census methods would be sure to not overlap in the event two random numbers were adjacent to each other (which did not occur).

Coarse Scale Mapping: These 30 stations were mapped during cruises OT-01-01 and FE-01-07-BL using the MiniBat TOV method outlined above. Additional small scale mapping was conducted at each station by making 0.25 nm "S" turns with the MiniBat at the interface between sand and coral, running parallel to the depth contour. The location of the reef/plain interface was determined using the ship's fathometer. Two or three passes were made over the original station coordinates. A list of the coordinates for the 30 permanent stations is given in Appendix I, Table 2. In addition, data from the FERREL SCS files, our own depth soundings using the MiniBat, and those from NOAA charts were combined (~ 0.5×10^{6} records) to provide a detailed chart product of the area.

Fine Scale Mapping: Divers were deployed at each station to establish permanent 30 m transects along the reef/plain interface. A temporary rebar stake and manta buoy were driven into the substrate at the immediate interface. A rebar stake and manta buoy were also placed 30 m from the interface marker out into the sand plain. Permanent markers were not established in the reef for fear of damage to corals. Five random sediment penetration and shear measurements were recorded at the immediate interface to assist in the calibration of seafloor sonar data. In addition, three random sediment cores were taken to determine sediment particle size.

Two, 30 m long video transects (corresponding to the two permanently established plain/reef transects) were collected at each permanent station in June/July 2001. The area sampled within each video frame was approximately 1 m^2. Six still images were selected from each transect at 2, 7, 12, 17, 22, and 27 m. Due to the high rugosity of some reef habitats, the height of the camera over the substrate varied resulting in a range of still frame field of views. To standardize our sampled area, a grid was overlaid onto each still image. The grid for each still was created using the width of the tape measure as seen in the video (1 cm) to create a scaled 10 cm x 10 cm grid within which a Braun Blanquet assessment of the community (sand, rock, algae (to species if possible), soft coral, encrusting coral, zoanthid, hard coral, and potentially, functional class - such as reef initiators, builders, and reproductive strategy) was made.

Seafloor Sonar Classification: Along with each MiniBat transect, QTC and ROXANN readings of seafloor composition were recorded in a GIS. These data are being compared for errors of omission, commission, and general agreement, both to each other and to the associated vertical video shot of the sites with the MiniBat-mounted camera.

Northern Boundary Assessment: The northern edge of TER North represents a unique opportunity to assess the impact and recovery of long-term trawling effects on deepwater (> 150') soft bottom communities. To that end, we have conducted ROXANN and bathymetric surveys of this interface, revealing it to be a very soft, almost gelatinous floc layer, but with significant fishery and primary production resources (Figure 7). We are continuing this comparative assessment with specially modified beam trawls (for fish and invertebrates) and Ponar grabs (for benthic microalgae), both within and outside the northern boundary. From these data, we will evaluate over time whether these soft bottom communities rebound from historic trawling pressure.

Fish Surveys:

Visual Census / Band transects: Paired band transect visual censuses were made over reef and soft bottom habitat along the entire length of the 30 m permanently established transects. Band transects were 6 m in width. Following fish censuses, video transects were recorded within the same two bands.

In addition, the top of Riley's Hump was broken into 34 strata, each 0.25 minutes of latitude and longitude. Ten strata were randomly selected for visual surveys. If upon arrival within a strata, water depth was greater than 110 feet, another strata was randomly chosen. Within each strata, two dive teams sampled either two or three 50 m transects. One dive team worked to the east of the anchor and the other dive team worked to the west of the anchor. Direction and spacing of transects was randomly determined prior to the dive. One member of the dive swam and counted all snapper and grouper along the transect. The other member video tape the transect. A total of 20 dives were made and 44 transects completed (Table 3).

Visual Census / Crepuscular observations: Crepuscular observations were made at a subset of the permanent stations. These observations were point counts made at the interface between reef and soft bottom. The aim of these point counts is to determine the relative abundance of predators patrolling the interface and schools of prey species preparing to leave the shelter of the reef for the soft-bottom feeding grounds. Visual census data has been entered and the data sets are currently being proofed.

Capture sampling: Fish and invertebrate sampling was conducted at all permanent sites. The soft bottom surrounding the banks was sampled for prey species with a 3-5 min, small fine-mesh trawl during the night. The diameter of the trawl was 2 m. The body of the net consisted of 7 mm mesh and the cod end 3 mm mesh. The net was towed on the bottom for three minutes to sample an area of ~100 m^2. Samples were preserved initially in formalin (24 h) and later transferred to ethyl alcohol. These samples have been sorted and the task of species identification begun.

Drifter release: To predict the fate of larvae spawned over Riley's Hump, WOCE/SVP drifters were released four times during cruise FE-00-09-BL in July 2000 and three times during cruise FE-01-10-BL in June/July 2001. During each occasion, three drifters were released over Riley's Hump (Appendix 1, Table 4). This information is central to understanding the potential role of Riley's Hump as a source area for settlement stage fishes to other reef habitats.

Ichthyoplankton: Ichthyoplankton sampling was conducted during both 2000 and 2001. A series of transects radiating from Riley's Hump were sampled (Table 5). A 60-cm bongo with 333 μm mesh nets was towed obliquely from the surface to a maximum depth of 100 m at each station. CTD casts were also made at each station to collect temperature and salinity data (Table 5).

Chlorophyll:

In order to investigate the contribution of various habitats in the TER to the food web supporting fishery resources, we collected a number of different sample types. We collected samples of benthic and water column chlorophyll from within the 30 permanent stations to estimate the biomass of benthic and planktonic microalgae. Benthic chlorophyll samples were collected with small cores by divers, and in deep waters (> 35 m) surface sediments were collected by a Ponar grab sampler. Surface waters were collected by either bucket or with a Niskin bottle. Subsurface, or bottom, water, was collected with a Niskin bottle. In addition to measuring chlorophyll in these samples, we also measured sediment particle-size and/or organic matter in a subset of the sediment samples, and we will measure nutrient concentration in a subset of the water samples. These measures give us additional information on the physico-chemical nature of the TER habitats.

Stable Isotope:

We also collected samples for use in a multiple stable isotope analysis of the food web supporting fish production in the TER. Samples collected from within the permanent stations included primary producers (phytoplankton, benthic microalgae, benthic macroalgae, seagrasses, and coral) and secondary consumers (fish, crabs, and shrimp). The amount of tissue required for stable isotope analysis is fairly small, about 200 mg dry weight is required for replicate analysis of C, N and S isotope ratios in organic matter. Adult fishes were sampled by hook and line from the FERREL and by divers armed with sling spears. This sampling targeted specific species from different levels of the food web to provide comprehensive data of the stable isotope composition of the fishes of the banks.

Fatty acids are another biomarker that provides information on the trophic linkages between habitats and fish. For a subset of samples, primarily reef fish, we also collected material for fatty acid analysis to explore the usefulness of this approach.

Ancillary Data:

We collected incident radiation and measures of water clarity at select stations. We recorded the GIS tracks of all bongo tows, beam trawls, drifters, water clarity stations and incident radiation stations. Two types of light data were collected. The first type, ambient light data, was collected by mounting a Licor 2 pi sensor on an upper deck of the ship. The data logger was programmed to collect ambient light data in micromoles • sec • m^{-1} at 10 min intervals from 0600 to 2000 h. Each night the data logger was downloaded and the data were archived in Excel spreadsheets. These ambient light data will be used to determine surface irradiance at specific times.

We also collected light profile data. At selected stations we lowered a 4 pi sensor over the gunnel of the ship and recorded light measurements at pre-determined depth intervals. In all cases, a light measurment was recorded at 1 m intervals for the first 5 m. The next 5 readings took place at either 1 or 2 m intervals depending on the water depth at the station. A minimum of 10 readings, at 10 different depths, constituted one profile. For each station, we collected three profiles. The light profile data were entered into Excel spreadsheets and extinction coefficients were calculated. The extinction coefficients will be used to calculate percent surface irradiance reaching the bottom, which will allow us to estimate productivity for selected habitats and make predictions about the distribution of benthic fauna and flora.

Outreach:

Several actions were taken to facilitate outreach, including posting all data on the CCFHR web site, hosting - along with NOAA ship FERREL - an open house showcasing the project's work, presentation of the work at the NC Seafood Festival, lectures, and national coverage on National Public Radio.

Sustainable Seas Expedition (TER South and Crepuscular Fish Migration):

This project received one formal day, plus follow-up work on a second day, of Deepworker dives on TER South, as well as crepuscular fish migration assessments at TER North. We requested dives focusing on areas deeper than 800 feet in TER South, to compliment surveys we conducted last year and others which we are coordinating with USGS. In addition, we tasked the Deepworker to sit in 150 feet of water at an interface site (S. Baumgartner, pilot) and to video tape and observe any crepuscular fish congregation and migration out onto the adjacent non-coral habitat. We were particularly interested to determine whether there are any changes in the occurrence of crepuscular fish migration off the reef onto the surrounding flats when there are structural guideposts (ie boulder fields - some kind of structure sprinkled out onto the flats) as opposed to clean coral/sand interface. If there are "hot spots" of migration that could be predicted from the landscape, it would allow us to make recommendations as to the level of protection that should be afforded certain features.

PRELIMINARY RESULTS

Habitat Characterization:

<u>Coarse Scale Mapping:</u> Mean depth (m), as well as minimum and maximum depths, for each permanent station were calculated in SAS, using depth data generated from MiniBat data files (Appendix I, Table 6). Additionally, average rugosity at each station was determined using the following method. Depth data were scaled and centered by subtracting the mean depth within in each of six pre-determined depth strata (0 -10 m, 10-20 m, 20-30 m, 30-40 m, 40-50 m, 50-60 m) from each depth observation in the MiniBat data files. This quantity was then divided by the standard deviation of the depth strata under consideration. The range of this scaled and centered data was then computed for each site and strata combination (Appendix I, Table 6). As an example, Figure 8 shows the variation in rugosity among sites

for the 20 - 30 m depth strata.

The combined FERREL SCS data, our MiniBat data, and NOAA chart soundings were combined to provide a detailed, georectified image of the major coral features and surrounding habitat of TER North (Figure 9). These data are being refined and will eventually be available in ARC/VIEW format.

Fine Scale Mapping: These videos are being interpreted and are under analysis.

Seafloor Sonar Classification: Extensive comparison between the QTC, ROXANN and video data is underway. The QTC system has proven difficult to apply effectively whereas the ROXANN system, which has been employed more frequently by our team, seems to be providing accurate assessments (Figure 10). Detailed analysis of omission and commission errors are underway, based on comparison with the associated video data.

Northern Boundary Assessment: Beam trawl and Ponar grab data are being processed. Interestingly, Deepworker video from proposed anchorage areas just to the north of this boundary revealed what may be the deepest *Halodule wrightii* or *Syringodium filiforme* beds on record (~ 120'). Material samples are needed from this area for verification.

Fish Surveys:

Visual Census / Band transects and Visual Census / Crepuscular observations: Visual census data from the 30 permanent stations has been entered and the data sets are currently being proofed.

Ten species of grouper and seven species of snapper were observed from the 44 transects at Riley's Hump (Table 7). Gray snapper were the most abundant species and mutton snapper were the fifth most abundant. Preliminary examination of the data indicates that there may be spatial differences in the distribution of snappers and groupers over Riley's Hump (Figure 11). Further analyses are required and ongoing. These data will provide a baseline from which to evaluate changes in the number of snapper and grouper in TER South over time.

Capture sampling: These samples have been initially sorted and the task of species identification begun.

Drifter release: Examination of the drifter tracks released during 2000 demonstrate that Riley's Hump can serve as a source of larvae to areas along the west Florida shelf (Figure 12 a-c), the Florida Keys and the east Florida shelf. Preliminary examination of the 2001 drifter releases shows similar variability in potential larval transport. The implications are, if spawning stock biomass of snapper and grouper increase in TER South, then increased larval supply can be expected across reef and estuarine systems throughout the southeastern United States.

Ichthyoplankton sampling: Drifter tracks from both years indicated very different flow dynamics to the north and south of Riley's Hump and the larval fish collections will allow determination of the species of fish influenced by the different flow regimes. These samples are being sorted and identified.

Chlorophyll / Stable Isotope:

All samples have been catalogued and are either being processed for analysis or have been sent to the contractor for analysis. Data from a sister project on the west Florida shelf, show that there is more microalgal biomass in the top 1 cm of sediment of the shelf than in the associated 20 m deep water column indicating that total benthic primary production exceeds water column primary production (Figure 13). In addition, stable isotope results from the west Florida shelf demonstrate that deepwater seagrass and associated algal communities on the sandy bottom of this area provide the base of the food chain supporting fishery organisms occupying the water column and hard bottom habitats indicating that regions once thought to be “barren” are indeed essential fish habitat (Figures 14 & 15).

Preliminary isotope data from samples collected in April 2001 suggest that, as found at the West Florida Shelf, benthic primary producers, including seagrasses and algae, are important components of the food web supporting fishery production. Shrimp collected from sites in the Open strata exhibit a carbon isotope signature very near to that of seagrass (e.g., *Halophila decipiens*) and/or benthic microalgae. Other commercially valuable species, such as snapper and grouper collected from the Park strata, exhibit a carbon signature indicative of a significant benthic algal input to the food web supporting their production. Future results will permit a more detailed analysis of the food web supporting fish production in the various habitats of the TER. However, these preliminary results, in conjunction with our prior results from the West Florida Shelf, suggest that the shallow water benthic habitats surrounding the coral reefs of the Tortugas Ecological Reserve will prove to be the source of a significant amount of the primary production ultimately fueling fish production throughout the TER.

Ancillary Data:

Tracking information for all samples is evident in the detailed chart products that have been developed. Light data are undergoing analysis. Tables 8 - 13 in Appendix 1 give dive statistics and summaries of all samples collected by cruise.

Outreach:

As per our agreement with the Sanctuaries and Reserve Division (SRD), all reports can be found at a new web site for this project: http://shrimp.ccfhrb.noaa.gov/~mfonseca/reports.html. On July 7th, 2001, the FERREL was moved to Mallory Square at Key West and was opened to the public. NOAA public relations, FKNMS staff, and CCFHR scientists displayed equipment, showed video and answered the questions of ~ 200 interested members of the public. Similarly, this work was showcased at a CCFHR booth at the NC Seafood Festival on October 6-7, 2001 in Morehead City, NC. This event, the second largest outdoor event in NC, brought at least 200 hundred people to the booth where sampling equipment and a video regarding this project was displayed; intense Q/A by staff was ongoing. This project was also the focus of a National Public Radio Radio Expedition, hosted by Alex Chadwick, which was broadcast nationally. These audio files may be accessed at: http://www.npr.org/programs/re/index_archive.html - select “Sanctuary for Tortugas Marine Life”. Finally, two presentations on this work were given; one at the FKNMS Science Advisory Panel meeting in

Marathon, FL, and the other at the weekly seminar series at Silver Spring, MD.

Sustainable Seas Expedition (TER South and Crepuscular Fish Migration):

Approximately 2 km of new video was shot by Deepworker at depths of ~1800 feet in TER South. These videos and associated track lines are stored at CCFHR and will be interpreted and plotted using GIS. Last year's NURC video on TER South is approximately half way completed. Every five seconds along the track lines there is a visual characterization recorded of the seafloor. These video are also being assessed for their utility as a fish census tool. Deepworker, piloted by S. Baumgartner, conducted several hours of surveillance during two evenings in early July 2001, working along the coral/sand interface, stopping and observing, and then moving on. Digital video was recorded at all times. We were not able to rig the sub with unobtrusive lighting and while large snapper aggregations at the reef edge were taped, the rapid migration out onto the sand/seagrass/algal areas observed repeatedly by Baumgartner were not taped. He was interviewed on tape immediately after his main dive to recount the species of fish, their behavior, and impressions of the activity. His testimony revealed that this phenomenon was striking and pervasive, providing qualitative evidence for the mechanism by which primary production on the seafloor surrounding the reef may be transferred back to the reef proper (i.e. as material in fish guts or as fish tissue fluxing across this interface). Besides crepuscular massing and migration, there appeared to be a hierarchy of species movement, beginning with larger grunts and ending with smaller species.

RESEARCH PLAN FOR 2002 (end of Phase I) AND BEYOND (Phase II)

End of Phase I - 2002:

Cruises Planned: We have six days at sea beginning April 24th, and 23 days beginning June 17th, both aboard the FERREL. The April cruise will focus on obtaining ground truth lines for associated aerial photography and obtaining a more detailed, landscape context for each permanent transect using side scan sonar (see Coarse Scale). The June/July cruise will focus on revisiting the permanent transects with divers and conducting other habitat/process characterization.

Habitat Characterization:

Coarse Scale Mapping: There will be additional work with this on several fronts. First, side scan sonar will be deployed at each permanent site to improve landscape context for assessment of community development. Second, additional transects will be taken in areas where there has been poor bathymetric coverage. Third, new transects will be run in areas that will ensure overlapping ground truth data with low level aerial photography and IKONOS imagery. This latter comparison is being performed so as to inform resource managers of the relative information richness, coverage, and accuracy that should be expected by using these various resource census tools, both here in the TER and elsewhere in NOAA's jurisdiction.

Fine Scale Mapping: Plans for next year's data collection are to have the videographer considerably closer to the substrate producing images with a smaller sampled area but significantly higher resolution. With this in mind, we are sampling the 2001 transect stills using a belt width of 40 cm. Within this 40 cm belt, randomly assigned points will be classified to as small a benthic category possible (see above), again using Braun Blanquet. These tapes are also available for assessment of coral disease status.

Seafloor Sonar Classification: We will add to this data base for purposes of building a comparative test among the two sonar systems (QTC vs ROXANN) and for the purposes of informing resource managers of the relative information richness, coverage, and accuracy that should be expected by using these various resource census tools, both here in the TER and elsewhere in NOAA's jurisdiction.

Northern Boundary Assessment: Sampling will be continued here. Additional video drifts may be added, especially in areas where deepwater seagrasses were detected by Deepworker.

Fish Surveys:

Visual Census / Band transects and Visual Census / Crepuscular observations: Daytime census work will be replicated. Crepuscular work will be curtailed to allow development of other sampling tasks.

Capture sampling: This work will be replicated to a large degree and may be augmented with SCUBA diver - based collections.

Drifter release: This work has been concluded. Extant data will now be linked with satellite imagery to produce an integrated assessment of water mass movement and its composition.

Ichthyoplankton sampling: This will be continued as before.

Chlorophyll / Stable Isotope:

This sampling will be replicated with an emphasis on developing compound-specific analyses.

Ancillary Data:

These data collections will continue (e.g. light regimes and tracking).

New Sampling Under Consideration:

Fish Assessments: We are experimenting with fixed camera deployments on the seafloor as a fish counting tool in an attempt to reduce diver demand. These were tested last year, using bait and a down-looking capability. We will experiment with horizontal sweeps this year.

Herbivory Assessment: Because of the potential for changes in trophic structure as the result of protection, particularly a trophic cascade resulting from an increase in pisciverous fishes - leading to a reduction in herbivorous fishes, we are experimenting with measures of relative herbivory intensity. Experiments were conducted this past cruise season where vegetable baits were deployed from the ship's launch for 24 h periods. Gear development issues dominated the work, leaving the opportunity for actual data collection this year.

Lobster Assessment: Because lobsters have shown a rapid response to protection elsewhere in the FKNMS, we are coordinating a sampling effort with the State of Florida FWCC out of Marathon to conduct lobster censuses at each of the permanent sampling sites.

Proposed Phase II - 2003 through 2005:

The baseline sampling in order to perform a before vs after comparison of the TER's ecology will have been completed in both TER North and TER South. Permanent transects have been surveyed and recorded in a GIS. It is now time to build the time series data set necessary to complete the comparison and evaluate the efficacy

of such a reserve. Collection of this *before* and *after* data provides a unique opportunity for NOAA to investigate the effects of human disturbance on the functioning of coral reef and seagrass ecosystems and to monitor the long-term effects of this reserve on the local and regional areas in terms of larval export, changes in adult biomass, and changes in ecosystem processes, particularly food webs. These data provide a direct assessment of the TER's effectiveness.

Statement of Work: Phase II of this project consists of 4 tasks:

Task 1. CCFHR will continue the time series assessment of the benthic resources at TER South, thus, completing a comparative analysis of changes in the sites' ecology as a result of Reserve status.

Task 2. Based on ongoing CCFHR drifter studies, as well as studies conducted by the University of Miami, regions of the shelf adjacent to the TER and the FKNMS are almost certainly an important source for larval recruits to these protected areas. CCFHR will identify larval fishes from depth-discrete icthyoplankton samples collected quarterly from 1998-2000 from shelf waters adjacent to the TER and the FKNMS and, using hindcasting techniques, the larval fish data will be combined with hydrographic sections of these areas to determine possible sources and routes of larval fish dispersal. These data represent the only collection with sufficient geographic and temporal range to address the larval source question. Moreover, these data will be joined with our decade-long database on larval and juvenile fish collections from Florida Bay to produce a comprehensive synthesis document on the early-life history of economically and ecologically important fishes in the region. This information on the life-history of the species occurring in and around the FKNMS and the TER is critical for predictions of fish dispersal capabilities from protected areas, directly addressing the efficacy of MPA's in general.

Task 3. CCFHR will continue the time series assessment of the food web at TER North and shall conduct a comparative analysis of its contribution to local fishery resources as a result of Reserve status. We will focus on these changes because the non-reef habitats may exhibit a significant shift in primary producer composition and abundance as the result of decreased disturbance expected with the imposition of the

TER.

Task 4. The CCFHR will conduct a comparative analysis of habitat composition and distribution as a result of Reserve status over time both at coarse, landscape scales (~ 10 m resolution) and fine scales (< 1 m resolution) along the permanent survey transects. Georectified videographic records of habitat distribution and bathymetric data will be examined using geostatistical methods to determine the change in scale of the benthic structure over time.

Schedule: April and June - July each year using NOAA research vessels.

Proposed budget: FY03 - FY05 -$280,000 per year - proportional distribution as is ongoing project

Products: Cruise reports and quarterly reports on an ongoing basis. Presentation to Sanctuaries - NCCOS at Silver Spring. At the end of each FY, CCFHR will provide a summary document describing what goals have been met over the course of the cruises in the form of these combined progress and cruise reports to OCRM/SRD and NOAA ship operations. Data will be easily accessible as all reports will be posted on our web site: http://shrimp.ccfhrb.noaa.gov/~mfonseca/reports.html.

REFERENCES

KC Lindeman, R Pugliese, GT Waugh, and JS Ault. 2000. Developmental patterns with a multispecies reef fishery: management applications for essential fish habitats and protected areas. Bull. Mar. Sci. 66(3):929-956.

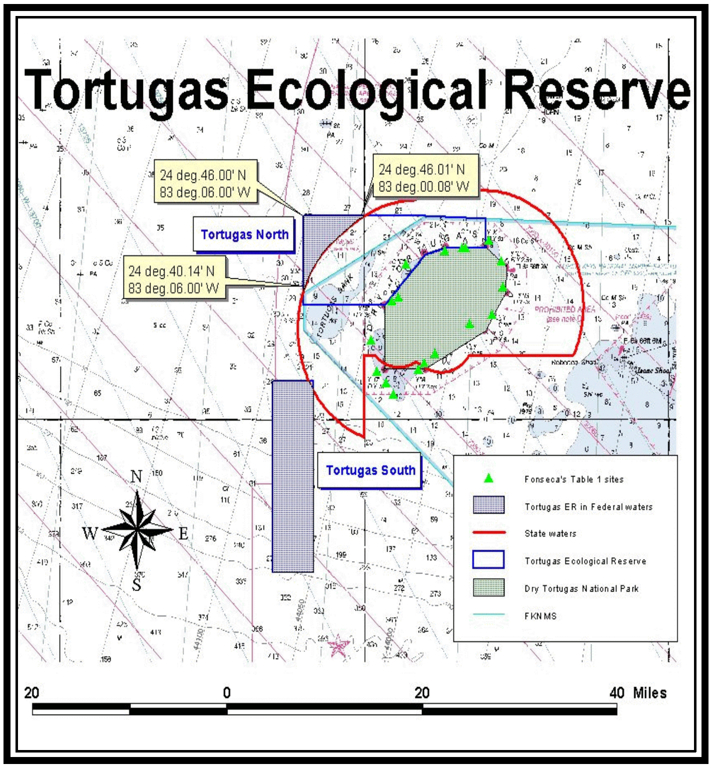

Figure 1. Boundaries of the Tortugas Ecological Reserve.

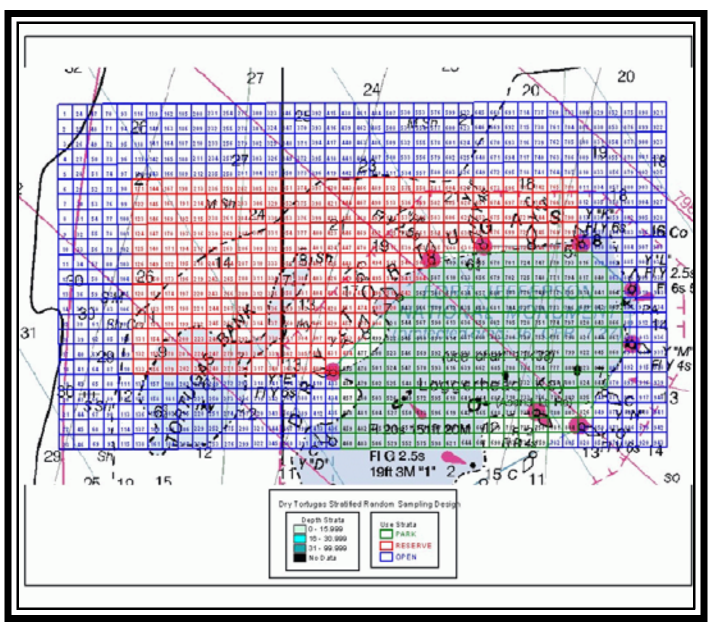

Figure 2. Random sampling universe based upon depth and use strata - FY 2000 sample design.

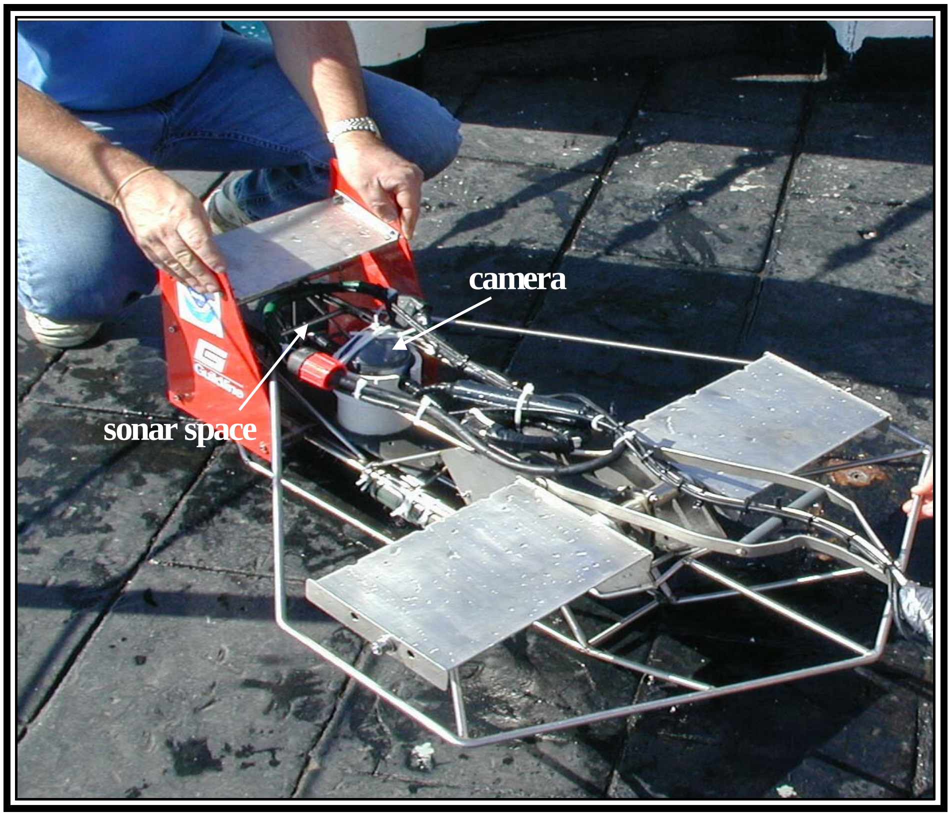

Figure 3. MiniBat® TOV.

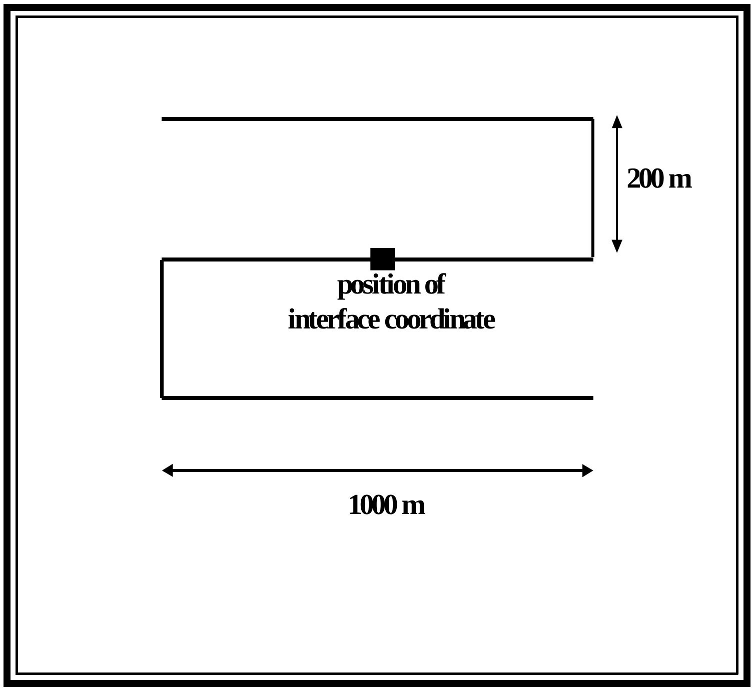

Figure 4. Tow path of the MiniBat® .

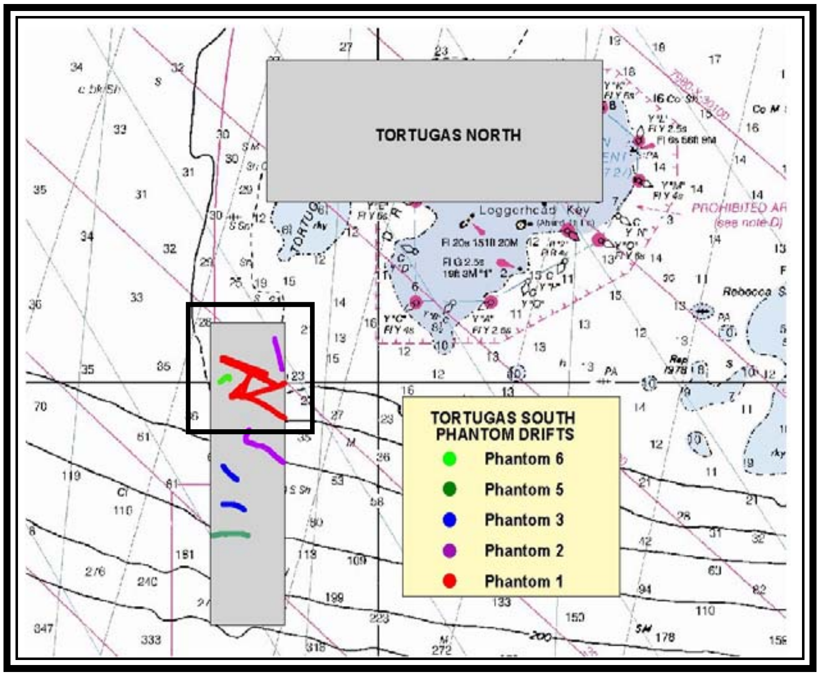

Figure 5. Tow tracks of the Phantom ROV.

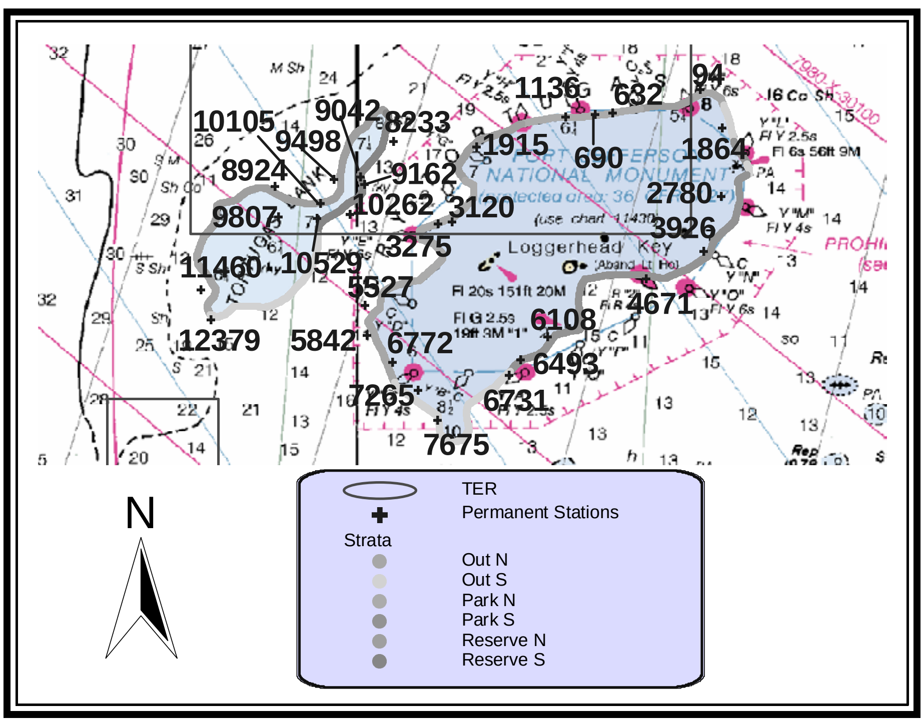

Figure 6. Thirty permanent stations.

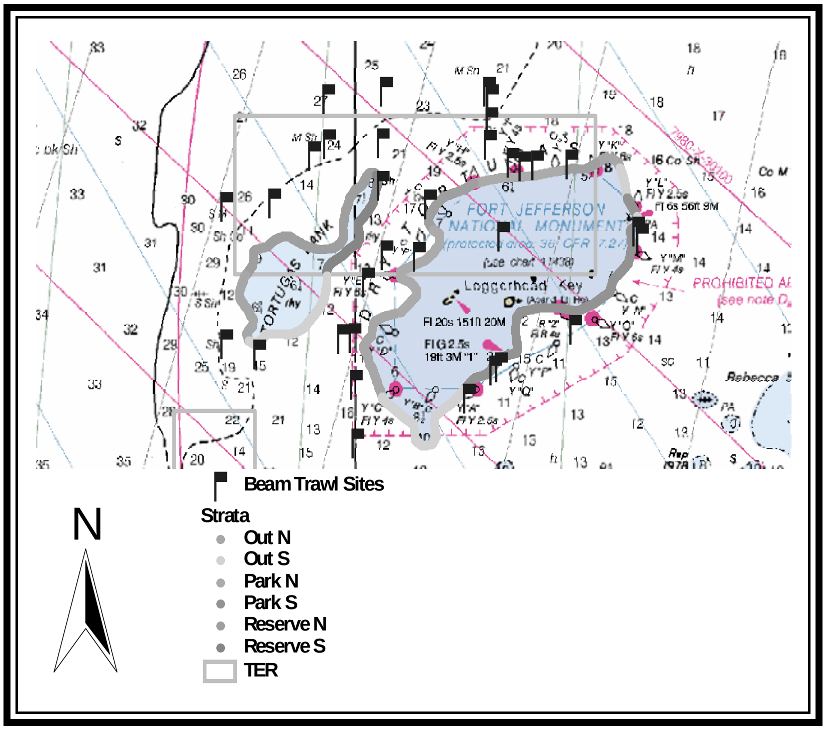

Figure 7. Location of beam trawl samples.

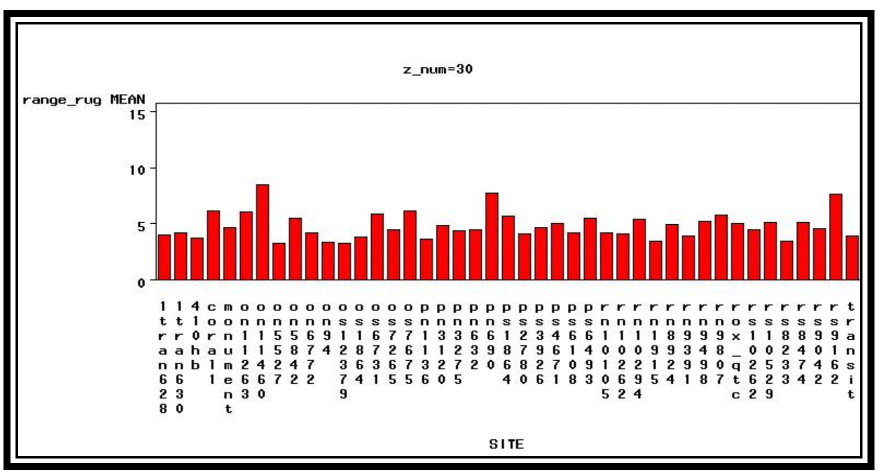

Figure 8. Variation in rugosity among the 30 permanent stations.

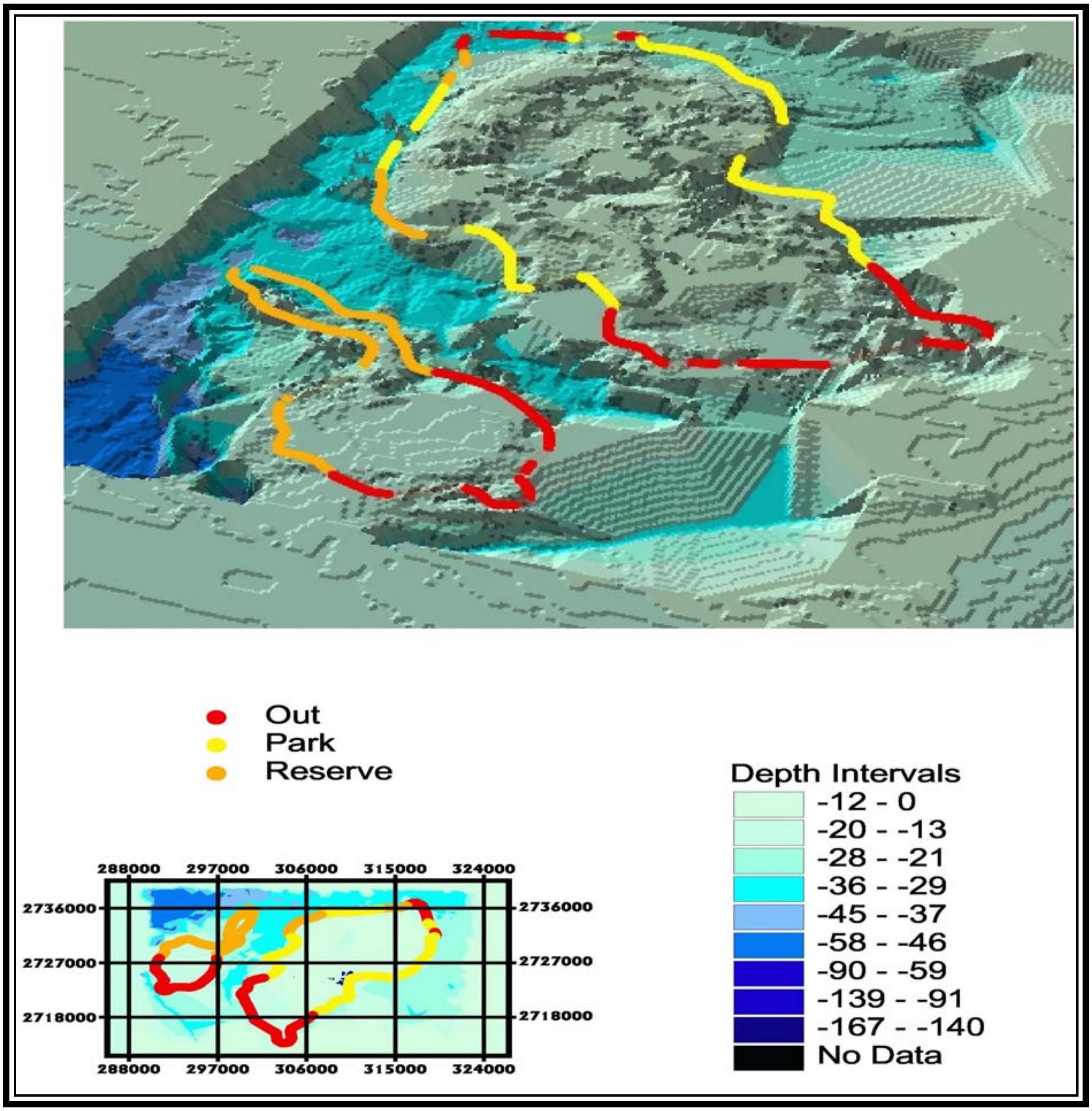

Figure 9. Major coral features and surrounding habitats of TER North.

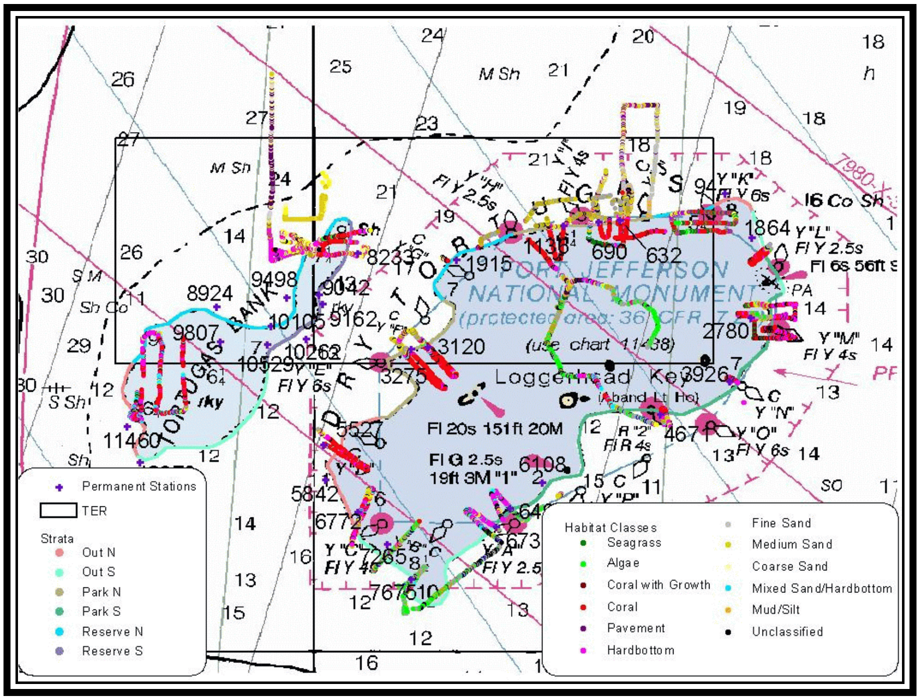

Figure 10. ROXANN tracks on selected permanent study sites.

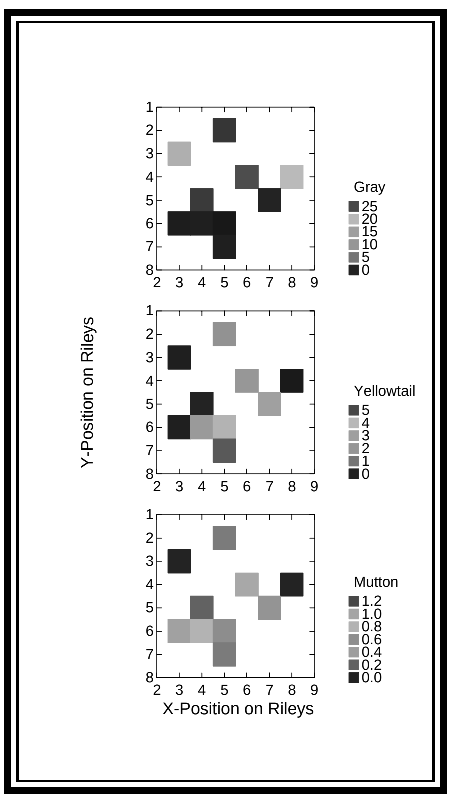

Figure 11. Spatial differences in the distribution of snappers and groupers over Riley's Hump.

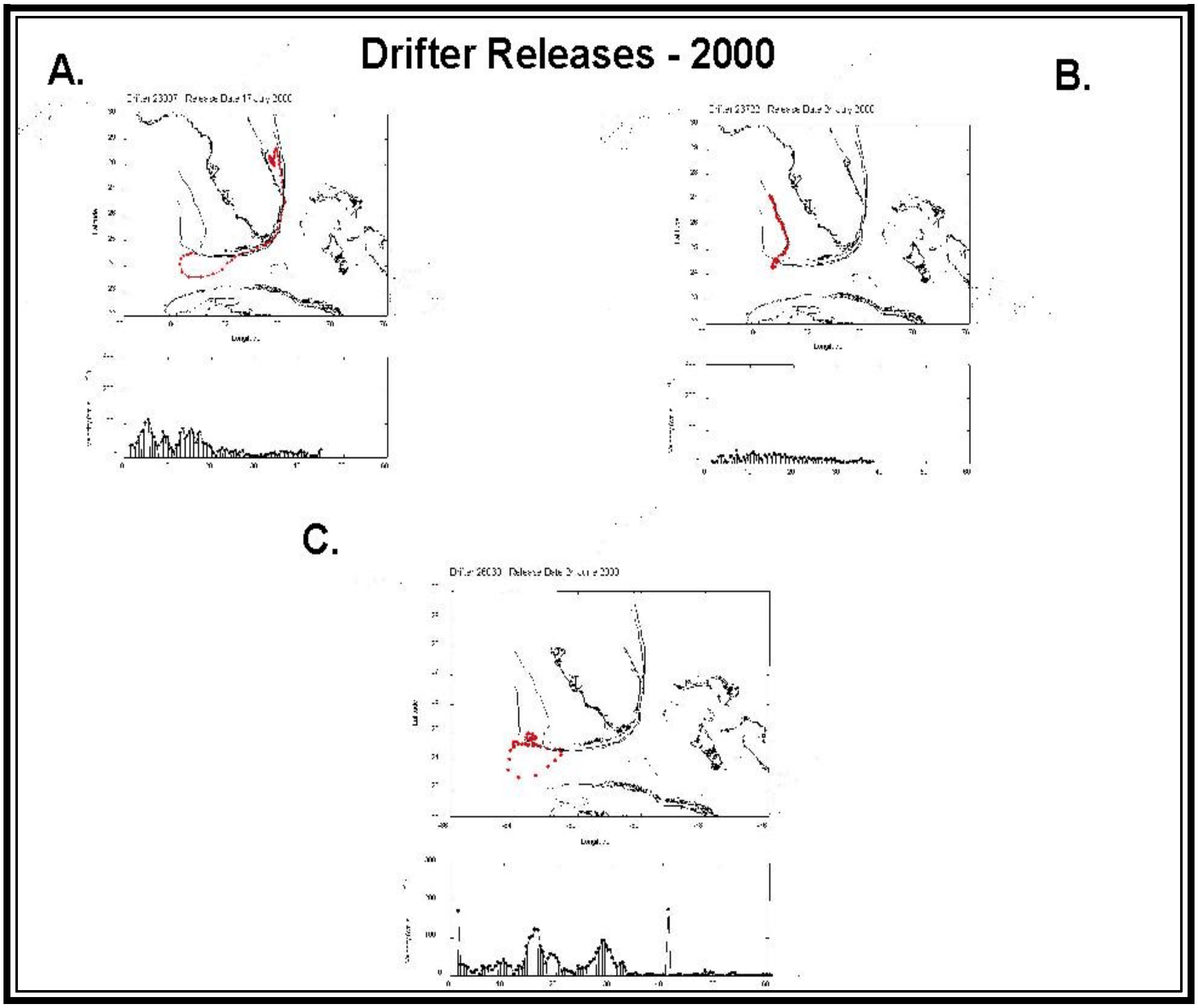

Figure 12. ARGOS drifter releases from Riley's Hump in year 2000. (A) shows west coast track, (B) shows east coast track, (C) shows local track.

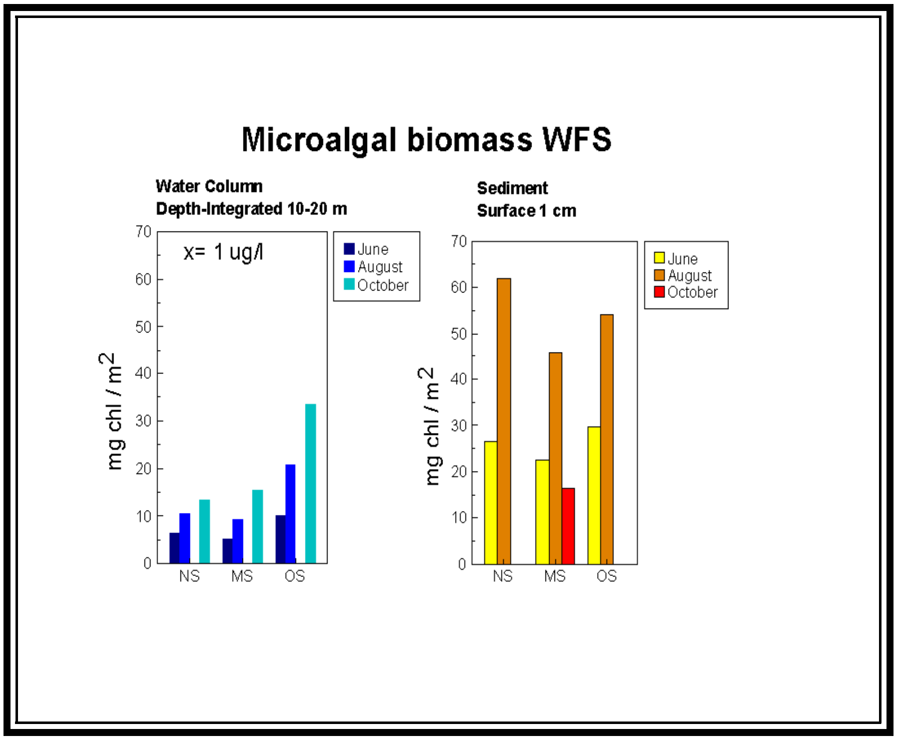

Figure 13. Differences in microalgal biomass (mg chl / m^2) from west Florida shelf habitats.

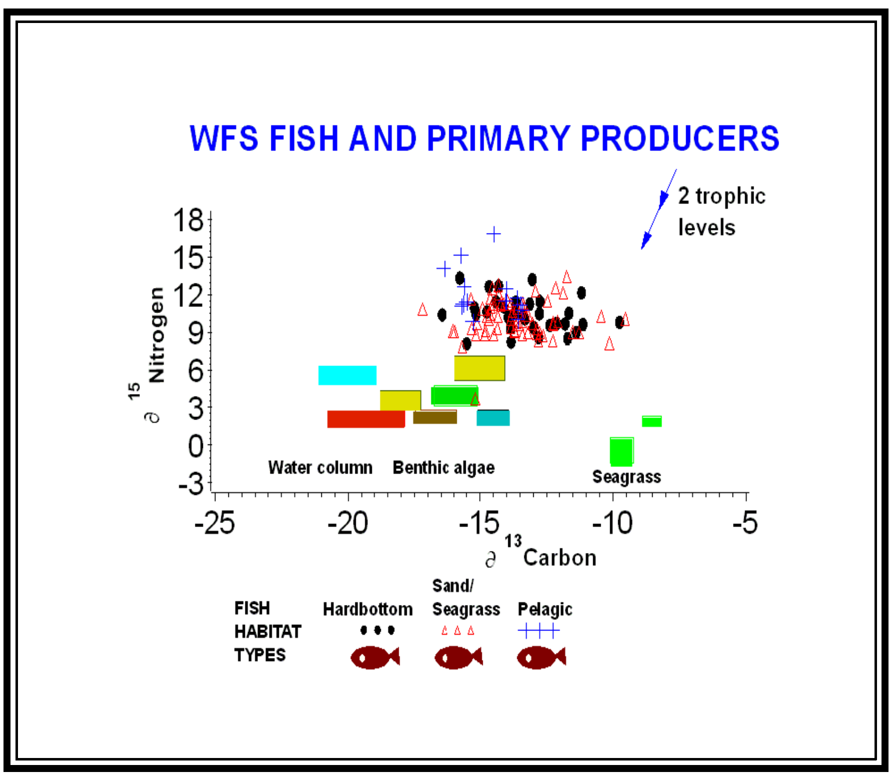

Figure 14. Comparison of stable isotope signatures for fish and primary producers on the west Florida shelf.

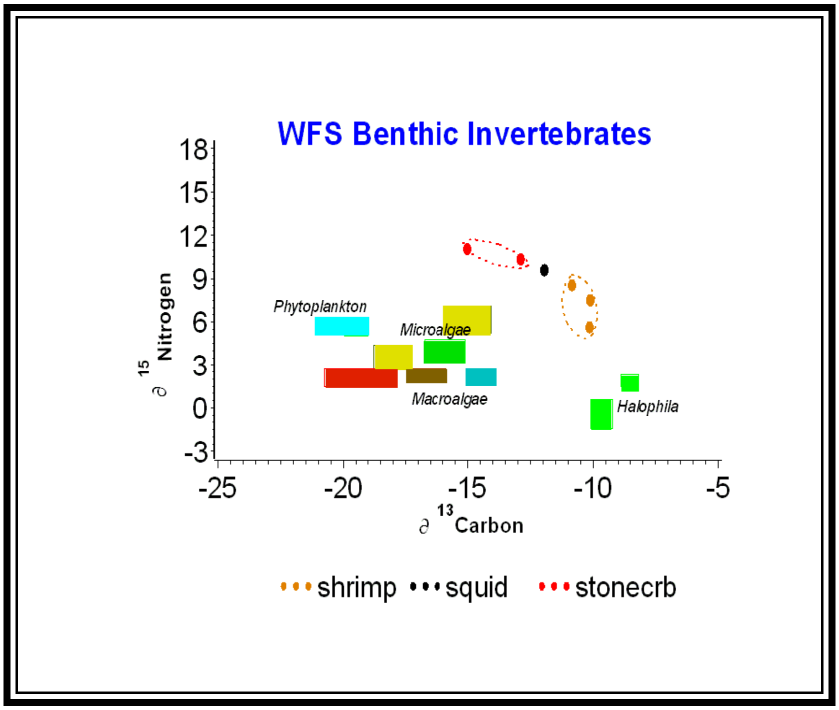

Figure 15. Comparison of stable isotope signatures for benthic invertebrates and primary producers on the west Florida shelf.

Appendix I, Table 2. Coordinates of thirty permanent stations.

Station ID	Latitude	Longitude	Depth @ Interface (ft)
RN1915	24.703150000	82.92815	100
RN9807	24.660900000	83.0467	63
RN10105	24.668816667	83.021566667	83
RN9498	24.683433333	83.013583333	75
RN8924	24.679250000	83.048716667	92
RS8233	24.706733333	82.97748333	104
RS9042	24.685183330	82.99746667	82
RS9162	24.680633333	82.9951	87
RS10262	24.662300000	83.003666667	91
RS10529	24.659585389	83.023301314	85
		AVERAGE DEPTH	86.2
ON5842	24.589100000	82.993966667	85
ON94	24.737799622	82.793482367	97
ON5527	24.607116670	82.994816667	100
ON6772	24.572633330	82.97785	72
ON11460	24.616700000	83.093316667	79
OS1864	24.715007833	82.780515	61
OS6731	24.564866183	82.908384117	80
OS7265	24.555500000	82.9628	79
OS7675	24.537416660	82.951066667	79
OS12379	24.598416667	83.08708333	103
		AVERAGE DEPTH	84.9
PN632	24.723883994	82.846429714	96
PN690	24.722817989	82.856984239	97
PN1136	24.721195739	82.874649469	99
PN3120	24.657728508	82.942727	87
PN3275	24.656763525	82.950820475	96
PS2780	24.673361295	82.780903483	54
PS3926	24.640229853	82.791548761	68
PS4671	24.623451044	82.825840933	79
PS6108	24.587854058	82.885310917	72
PS6493	24.574495475	82.901414336	78
		AVERAGE DEPTH	84.2

Appendix 1, Table 3. Transect locations for fish visual censuses on Riley's Hump.

Strata	Latitude	Longitude
Strata 1	24o 30.589'N	83o 06.975'W
Strata 3	24o 30.481'N	83o 07.427'W
Strata 13	24o 30.052'N	83o 06.682'W
Strata 15	24o 29.830'N	83o 06.058'W
Starta 18	24o 29.967'N	83o 07.096'W
Strata 21	24o 29.898'N	83o 06.318'W
Strata 24	24o 29.558'N	83o 07.302'W
Strata 25	24o 29.577'N	83o 07.154'W
Strata 26	24o 29.627'N	83o 06.958'W

Appendix 1, Table 4. Drifter release locations.

Release Location	Latitude	Longitude
Release 1	24^{o} 29.028 N	083^{o} 06.102 W
Release 2	24^{o} 29.970 N	083^{o} 06.974 W
Release 3	24^{o} 28.946 N	083^{o} 08.056 W

Appendix 1, Table 5. Bongo and CTD station data from July 2001 cruise. Sampling effort and locations were nearly identical during July 2000.

Station	Date	Time (EST)	Lat	Long	Tasks
4	7/16/2001	2043	24o29.776 N	083o07.053 W	CTD/Oblique Bongo
5		2137	24o33.763 N	083o10.082 W	CTD/Oblique Bongo
6		2237	24o38.034 N	083o13.110 W	CTD/Oblique Bongo
7		2333	24o42.126 N	083o16.227 W	CTD/Oblique Bongo
8	7/17/2001	35	24o46.559 N	083o19.583 W	CTD/Oblique Bongo
9		129	24o50.597 N	083o23.024 W	CTD/Oblique Bongo
10		225	24o55.223 N	083o24.311 W	CTD/Oblique Bongo
11		314	24o58.963 N	083o27.693 W	CTD/Oblique Bongo
16		2045	24o29.779 N	083o07.430 W	CTD/Oblique Bongo
17		2134	24o27.914 N	083o12.451 W	CTD/Oblique Bongo
18		2309	24o21.622 N	083o21.224 W	CTD/Oblique Bongo
19	7/18/2001	103	24o13.794 N	083o33.921 W	CTD/Oblique Bongo
20		237	24o08.365 N	083o43.402 W	CTD/Oblique Bongo
12		2106	24o24.541 N	083o06.661 W	CTD/Oblique Bongo
13		2218	24o19.555 N	083o07.362 W	CTD/Oblique Bongo
14	7/19/2001	2352	24o09.712 N	083o07.103 W	CTD/Oblique Bongo
15		159	23o54.279 N	083o07.115 W	CTD/Oblique Bongo
21		2100	24o29.418 N	083o07.260 W	CTD/Oblique Bongo
22		2157	24o25.824 N	083o01.989 W	CTD/Oblique Bongo
23		2323	24o19.924 N	082o54.928 W	CTD/Oblique Bongo
24	7/20/2001	128	24o10.134 N	082o43.040 W	CTD/Oblique Bongo
25		338	24o00.535 N	082o30.658 W	CTD/Oblique Bongo
3		2148	24o23.016 N	082o51.961 W	CTD/Oblique Bongo
2	7/21/2001	0	24o21.066 N	082o32.178 W	CTD/Oblique Bongo

26		158	24o17.007 N	082o15.590 W	CTD/Oblique Bongo
27		347	24o19.949 N	082o00.369 W	CTD/Oblique Bongo
28		508	24o25.197 N	081o52.250 W	CTD/Oblique Bongo

Appendix I, Table 6. Mean, minimum, maximum depths (m) for each permanent station, based upon MiniBat® data files.

Site	Mean Depth	Min Depth	Max Depth	Depth Range
on11460	19.4	11.8	36.2	24.4
on5527	21.8	11.6	33.3	21.7
on5842	22.4	3.7	28	24.3
on6772	19.4	11	50.1	39.1
on94	21.0	3.3	31.5	28.2
os12379	21.8	13.3	32.3	19
os1864	16.1	11.7	23.4	11.7
os6731	15.1	9.4	27.7	18.3
os7265	21.4	12.7	52.6	39.9
os7675	20.9	16.5	23.6	7.1
pn1136	18.7	7.9	32.7	24.8
pn3120	19.2	5.8	29.6	23.8
pn3275	20.8	4.1	32.2	28.1
pn632	25.0	7.8	32.1	24.3
pn690	24.7	13.3	30.8	17.5
ps2780	14.4	5.5	25.5	20
ps3926	20.5	3.9	27.9	24
ps4671	20.4	4.2	27.2	23
ps6108	18.5	4.2	27.5	23.3
ps6493	16.8	3.4	29.8	26.4
rn10105	21.3	14.7	30.3	15.6
rn1915	21.6	11.3	33.5	22.2
rn8924	22.1	15.4	25.7	10.3
rn9498	18.1	14.9	22.2	7.3
rn9807	19.8	5.49	25.5	20.01
rs10262	25.0	19.1	28.3	9.2
rs10529	20.3	14.9	25.1	10.2
rs8233	24.0	12.7	33.1	20.4
rs9042	23.2	16	27.6	11.6
rs9162	23.2	3.8	28	24.2

Appendix I, Table 7. Observed fish species along Riley's Hump transects.

Common Name	Fish Abundance (50 m)	Family
Black grouper	0.26	Grouper
Red Grouper	0.19	Grouper
Graysby	0.12	Grouper
Coney	0.09	Grouper
Red Hind	0.07	Grouper
Rock Hind	0.07	Grouper
Yellowfin Grouper	0.07	Grouper
Scamp	0.06	Grouper
Nassau	0.02	Grouper
Yellowmouth Grouper	0.02	Grouper
Gray Snapper	5.38	Snapper
Yellowtail Snapper	1.53	Snapper
Mutton Snapper	0.44	Snapper
Dog Snapper	0.07	Snapper
Cubera Snapper	0.05	Snapper
Red Snapper	0.02	Snapper
Creole Fish	0.58	Wrasse
Hogfish (Labridae)	0.50	Wrasse

Appendix I, Table 8. Dive statistics for cruise FE-01-07-BL.

# Divers	Total # Dives	Average Depth (ft)	Total Bottom Time (min)	Average Bottom Time (min)
13	55	68.5	1273	32.7

Appendix I, Table 9. Dive statistics for cruise FE-01-10-BL and FE-01-10-BL.

# Divers	Total # Dives	Average Depth (ft)	Total Bottom Time (min)	Average Bottom Time (min)
18	157	81.7	5136	32.7

Appendix I, Table 10. Sample code definitions.

Code	Sample Type
FVT	fish video transect
FVC	fish visual census
SS	SCUBA seine (towed underwater by divers)
TUCK	Tucker trawl
BB	Braun-Blanquet habitat assessment by divers
CHL_BEN	sediment core by divers or from PONAR grab for benthic chlorophyll analysis
CHL_COL	water column sample taken from ship for chlorophyll analysis
NUT_COL	water column sample taken from ship for nutrient analysis
SI_PHYT	phytoplankton sample from water column for stable isotope analysis
SI_FISH	fish collected by divers or taken from beam trawls for stable isotope analysis
SI_INV	invertebrate collected by divers for stable isotope analysis
SI_MAC	macroalgal sample taken by divers for stable isotope analysis
SI_MIC	microalgal sample taken from sediment core by divers for stable isotope analysis
SI_SG	seagrass sample taken by divers for stable isotope analysis
SI_COR	coral sample taken by divers for stable isotope analysis
BAT	transect made with MiniBat® Towed Operated Vehicle
BONG	bongo tow
ROV	transect made with Phantom Remote Operated Vehicle S-2
CTD	CTD cast
BEAM	beam trawl
DROP	drop camera assessment
SLED	towed video sled transect
LGT	water column light profile taken from ship using LICOR
SEC	water column Secchi disk reading from ship
QTC	sonar trace from Quester Tangent SeaView® sonar system
ROX	sonar trace from ROXANN® sonar system
DRIFT	ARGOS drifter deployed
WPT	waypoint taken either in Trimble® or in ASPEN
DIVE	divers down
PONAR	Ponar grab sample
SED_PEN	sediment penetration measurement by divers or taken from a PONAR grab sample

SED_SHR	sediment shear measurement taken by divers or taken from a PONAR grab sample
SED_PART	sediment core taken by divers or from a PONAR grab for particle size analysis
SVHS	video recorded using Super VHS VCR
VHS	video recorde using VHS VCR
ASP	ASPEN file collected
HABTRAN	video transect of benthic habitat taken by diver
HERB	herbivory experiment deployed
LGT_METER	download of incident radiation data taken by LICOR
FSHCAM	stationary tripod with downfacing video camera to record fish movement

Appendix I, Table 11. Samples collected during cruise OT-01-01.

Site	Samples
OS12379	QTC, BAT, ASP, VHS, SVHS, PONAR, SED_PART
ON11460	BAT, ASP, VHS, SVHS, DROP, PONAR, SED_PART, LGT, SEC
ON11263	QTC, BAT, ASP, VHS, SVHS, PONAR, SED_PART
RN10294	QTC, BAT, ASP, VHS, SVHS
RN9391	QTC, BAT, ASP, VHS, SVHS, DROP, WPT
RN9807	QTC, BAT, ASP, VHS, SVHS
RS10105	QTC, BAT, ASP, VHS, SVHS
RS10262	QTC, BAT, ASP, VHS, SVHS
RS9162	QTC, BAT, ASP, VHS, SVHS
RS9042	QTC, BAT, ASP, VHS, SVHS
RS8474	QTC, BAT, ASP, VHS, SVHS, ROX
misc station in reserve	QTC, BAT, ASP, VHS, SVHS, ROX
west end of northern reserve boundary	QTC, BAT, ASP, ROX
mid region of northern reserve boundary	QTC, BAT, ASP, ROX, SVHS, PONAR, DROP, BEN_CHL, SED_PART, SED_PEN, SED_SHR
east end of northern reserve boundary	QTC, BAT, ASP, ROX, SVHS, PONAR, DROP, BEN_CHL, SED_PART, SED_PEN, SED_SHR

Appendix I, Table 12. Samples collected during cruise FE-01-07-BL.

Site	Samples
PN632	QTC, BAT, ASP, ROX, VHS, SVHS, WPT, FSHCAM, BEAM, LGT, DIVE
PN690	QTC, ASP, VHS, SVHS, LGT, BEAM, DIVE
PN1136	QTC, BAT, ASP, ROX, VHS, SVHS, WPT, DIVE, BEAM, LGT_METER, SI_INV
RN1915	QTC, BAT, ASP, ROX, VHS, SVHS, BEAM, FSHCAM, SI_FISH, SI_INV
PS4671	QTC, BAT, ASP, ROX, VHS, SVHS, DIVE, BEAM
PS3926	QTC, BAT, ASP, VHS, SVHS, WPT, LGT, DIVE
PS2780	QTC, BAT, ASP, VHS, SVHS, BEAM, DIVE
PS1864	QTC, BAT, ASP, VHS, SVHS, DIVE
ON94	QTC, BAT, ASP, VHS, SVHS
misc site in park basin	QTC, BAT, ASP, ROX, VHS, SVHS, DIVE
PS6108	QTC, BAT, ASP, ROX, VHS, SVHS, DIVE
PS6493	QTC, BAT, ASP, ROX, VHS, SVHS, DIVE
OS6731	QTC, BAT, ASP, ROX, VHS, SVHS, DIVE
OS7675	QTC, BAT, ASP, ROX, VHS, SVHS, DIVE
PN3275	DIVE
PN3120	DIVE

Appendix I, Table 13. Samples collected during cruises FE-01-10-BL and FE-01-10-BL.

Site	Samples
OS12379	WPT, DIVE, QTC, BAT, ASP, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, LGT, SEC
ON11460	WPT, DIVE, QTC, BAT, ASP, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, SI_FISH, HERB
RNBOUNDM	BEAM, ASP
ONBOUNDM	BEAM, ASP
RS10262	WPT, DIVE, QTC, BAT, ASP, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, LGT, SEC, BEAM, CHL_BEN
RS9042	WPT, DIVE, QTC, BAT, ASP, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, BEAM, CHL_BEN
OS7265	WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, BEAM, CHL_BEN, NUT_COL, CHL_COL, SI-COR
ON6772	WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, BEAM, NUT_COL, CHL_COL, SI_PHYTO, CHL_BEN, SI_COR
ON5527	WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN
OS7675	WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN
PN3275	BEAM, NUT_COL, CHL_COL, SI_PHYTO, SI_MIC, WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN
PS2780	NUT_COL, CHL_COL, SI_PHYTO, SI_MIC, WPT, DIVE, QTC, BAT, ASP, SVHS, VHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, SI_FISH
RNBOUNDE	BEAM, ASP, SI_FISH, PONAR, SI_PHYTO, SED_PART, CHL_COL, SI_MIC
ONBOUNDW	BEAM, ASP, SI_FISH
RNBOUNDW	BEAM, ASP, SI_FISH
Tortugas South	DRIFT, ASP
RS8233	WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, SI_MIC, BEAM, LGT
RS9162	WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, SI_MIC, BEAM, LGT
RS10529	BEAM, ASP, SI_FISH, SI_INV, SI_PHYTO, CHL_COL, LGT, SEC, WPT, DIVE, QTC, BAT, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN
ON5842	WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, SI_PHYTO, CHL_COL, SI_MICRO, BEAM, SI_FISH
PN3120	WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, SI_MIC, SI_PHYTO, CHL_COL
ON11460	BEAM, ASP, SI_FISH, SI_INV
RN9498	WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, SI_MIC, SI_PHYTO, CHL_COL
RN1915	WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, SI_MIC, SI_PHYTO, CHL_COL, LGT, SEC, BEAM, SI_INV

RN8924	**WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, SI_PHYTO, CHL_COL, SI_INV, SI_FISH, NUT_COL, LGT, SEC, BEAM**
ON94	**WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, CHL_COL, SI_PHYTO**
OS1864	**WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN**
OS6731	**WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, CHL_COL, SI_PHYTO**
Tortugas South	**DRIFT, ASP, NUT_COL, CHL_COL**
OS12379	**NUT_COL, CHL_COL, SI_PHYTO, SI_FISH, SI_INV, BEAM**
channel b/w Tortugas South and Fort Jefferson	**BEAM, ASP, SI_MAC**
PS6108	**WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, NUT_COL, CHL_COL, SI_PHYTO, SI_MIC, SI_SG, SI_MAC, LGT**
PN1136	**WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, NUT_COL, CHL_COL, SI_PHYTO,**
PS3926	**WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, NUT_COL, CHL_COL**
RN10105	**QTC, BAT, ASP, VHS, SVHS, NUT_COL, CHL_COL**
RN9807	**WPT, DIVE, FVC, SI_FISH**
PN690	**DIVE, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, NUT_COL, CHL_COL, SI_MAC, SI_MIC,**
PN632	**DIVE, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, SI_MIC, LGT**
PS4671	**WPT, DIVE, QTC, BAT, ASP, VHS, SVHS, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, NUT_COL, CHL_COL, SI_PHYTO, SI_FISH, SI_MIC**
PS6493	**DIVE, SED_PART, SED_PEN, SED_SHR, HABTRAN, FVC, CHL_BEN, SI_FISH, LGT**